International Journal of Future Generation Communication and Networking
Vol. 9, No. 6 (2016), pp. 201-210
http://dx.doi.org/10.14257/ijfgcn.2016.9.6.19

A Novel Machine Selection Method Combining Group Eigenvalue Method with TOPSIS Method

Tonghua Yang[1, 2], Shenghua Xu[1] and Neal N. Xiong[1*]

[1]School of Information Technology, Jiangxi University of Finance and Economics, Nanchang, 330032, China

[2]School of Vocation Teachers, Jiangxi Agricultural University, Nanchang, 330045, China

E-mails: Yangth883@163.com, jxcdxsh@foxmail.com, xiongnaixue@gmail.com

Abstract

Machine selection is an important step in the process of manufacturing. The selection process needs to consider some selection attributes simultaneously from a set of candidate machines. The attribute weights are important for the result of machine selection problem, but the most used AHP method has the shortcoming. Thus this paper will develop a new weighting method based on the concept of group eigenvalue method. Then the new machine selection method is proposed by combining group eigenvalue method with TOPSIS method. Two practical examples demonstrate that the proposed method has more effectiveness and feasibility.

Keywords*: machine selection, group eigenvalue method, multi-attribute decision making, TOPSIS*

1. Introduction

Fierce economic competition has spurred the manufacturing firms to improve and invest in modern equipment to satisfy the needs of the market [1]. Machine tool selection plays a primary role in the improvement of productivity and flexibility in the manufacturing environment. Manufacturing firms worldwide are forced to undergo transformation processes in order to improve their ability to succeed with their products on extremely competitive international markets [2]. The selection of most desirable machine is to select a best machine from a set of candidate machines according to several given evaluation attributes. The machine selection problem is actually a multi-attribute decision making problem, and it has received great attention by many authors. There are many selection methods are developed for machine selection problem. Nguyen et al. [1] developed the hybrid approach of the fuzzy ANP (Analytic Network Process) and COPRAS-G (Complex Proportional Assessment of alternatives with Grey relations) for machine selection problem with the consideration of the interactions of the attributes. Aloini et al. [2] developed the TOPSIS method for solving packaging machine selection problem, in which the selection attribute are expressed with intuitionistic fuzzy (IF) numbers. Jahromi et al. [3] proposed a novel 0-1 integer programming model for solving a problem of dynamic machine-tool selection and operation allocation with part and tool movement policies under a flexible manufacturing system environment. Moon et al. [4] proposed a 0− 1 integer programming combining with genetic algorithm for solving the machine tool selection problem. Flexible manufacturing cells (FMCs) have received great attention in today's dynamic manufacturing environment [5]. Under flexible manufacturing system environment, Chtourou et al. [6] developed an expert system for manufacturing systems machine selection; Chan et al. [7-8] put forward a fuzzy goal-

ISSN: 2233-7857 IJFGCN

programming approach to solve the machine tool selection problem. Rao [9] developed the digraph and matrix methods for the machine group selection in a FMC.

This paper will develop a new evaluation method to solve the problem of machine selection in a flexible manufacturing cell. The remains of this paper are organized as follows. In Section 2, this paper is given the introduction of group eigenvalue method. In Section 3, this paper is constructed a MADM model for machine selection problem, and put forward the new evaluation method. In Section 4, two examples of machine selection in flexible manufacturing cell are given to demonstrate the feasibility and effectiveness of the new evaluation method. Finally, Section 5 is given the conclusion and future extend work of this paper.

2. Group Eigenvalue Method

Group eigenvalue method, firstly proposed by Qiu in 1997, is a good group decision method [10]. This method fixes the attribute weights by constituting experts' judgment matrix, and this method does not need to test the consistency of judgment matrix. In this point, it is an advantage over AHP method, and thus also leads the group eigenvalue method more simple and convenient [11-16].The detailed conception and steps of group eigenvalue method are given as follows [10]:

It is usually impractical to request perfect evaluation from one expert because one person’s knowledge and experience cannot be all-inclusive [17-18]. To integrate experts’ evaluations, suppose there is an idealized expert, whose has the highest decision reliability level, and assume the evaluation result of this expert is consistent with those of other experts. The ideal evaluation vector of the idealized expert can be expressed with vector $X^* = (x_1^*, x_2^*, ..., x_n^*)^T$. The summation of angle values between the idealized expert’s evaluation vectors with every other expert’s evaluation vector should be the minimum. Thus, X* can be solved out from the following equation:

$$\max_{\|b\|=1} \sum_{i=1}^{m} (b^T X_i)^2 = \sum_{i=1}^{m} (X^{*T} X)^2 = \rho_{\max} \tag{1}$$

Here $\rho_{\max}$ is the maximum single eigenvalue of matrix $X^T X$. X^* is the positive eigenvector corresponding to $\rho_{\max}$ and $\| X^* \| = 1$. The parameter b is the weight vector, which satisfies $\forall b = (b_1, b_2, ..., b_n)^T \in E^n$ and $\| b \| = 1$, with E denoting the Euclid vector space. Each expert’s standardized weight vector can be obtained after the eigenvector is normalized corresponding to the maximum eigenvalue.

To obtained attribute weights, the following introduction will give the detail calculation approach:

(i) Calculate the matrix $F = X^T X$;

(ii) Then use the Matlab software to obtain the largest eigenvalue $\rho_{\max}$ of matrix F , and then the corresponding eigenvector with respect to $\rho_{\max}$ is $X^* = (X_1^*, X_2^*, ..., X_n^*)$.

At last, normalize the eigenvector to form the indicators' weights vector which is also called "the ideal expert's scoring vector".

(iii) Thus the ideal expert’s scoring vector, which in this paper is the attribute weight vector with the following form:

$$W = (w_1, w_2, ..., w_n) , \tag{2}$$

where

$$w_j = X_j^* / \sum_{k=1}^{m} X_k ,\ j = 1, 2, ..., n . \tag{3}$$

3. New Machine Selection Method

In this section, we will develop a new machine selection method, the steps of the new method is given as follows:

Step 1. Find out all possible the candidate machines (alternatives), selection attributes and its measures for the given application.

Step 2. Establish the MADM decision matrix.

The solving each MADM problem begins with constructing decision matrix. Let $X=\{x_1,x_2,\cdots,x_m\}$ be a set of alternative, $O=\{o_1,o_2,\cdots,o_n\}$ be a set of decision attributes or criteria, a_{ij} is the performance of alternative x_i ($i=1,2,\cdots,m$) on the attribute o_j ($j=1,2,\cdots,n$). Then the machine selection problem can be expressed with the following decision matrix form:

$$A=(a_{ij})_{m\times n}=\begin{array}{c} \\ x_1 \\ x_2 \\ \vdots \\ x_m \end{array}\begin{array}{c} \begin{array}{cccc} o_1 & o_2 & \cdots & o_n \end{array} \\ \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{pmatrix} \end{array} \quad (4)$$

Step 3. Normalize the decision matrix A into normalization decision matrix $R=(r_{ij})_{m\times n}$.

The process of transforming attributes value into a range of [0,1] is called normalization and it is required in MADM methods to transform performance rating with different data measurement unit in a decision matrix into a compatible unit [19-21]. The normalization method adopted from the paper [22], and the formulas are given as follows:

$$r_{ij}=x_{ij}\,/\sqrt{\sum_{i=1}^{m}x_{ij}^2}$$

Step 4. Define the positive ideal solution (PIS) and the negative ideal solution (NIS).

The PIS is $r^*=(r_1^*,r_2^*,\cdots,r_n^*)$; The NIS is $r^-=(r_1^-,r_2^-,\cdots,r_n^-)$. Here, if the *j*-th attribute is the benefit attribute, which is the larger the better attribute, then $r_j^*=\max_{1\le i\le m}\{a_{ij}\}$, $r_j^-=\min_{1\le i\le m}\{a_{ij}\}$; If the j-th attribute is the cost attribute, which is the smaller the better attribute, then $r_j^*=\min_{1\le i\le m}\{a_{ij}\}$, $r_j^-=\max_{1\le i\le m}\{a_{ij}\}$.

Step 5. Calculate the distance measure for each alternative to PIS and NIS using the following equations:

$$D_i^*=\sqrt{\sum_{j=1}^{n}w_i^2(r_{ij}-r_j^*)^2} \quad (5)$$

and

$$D_i^-=\sqrt{\sum_{j=1}^{n}w_i^2(r_{ij}-r_j^-)^2} \quad (6)$$

Step 6. Calculate the relative closeness to the ideal solution according to the following equation:

$$C_i=\frac{D_i^-}{D_i^-+D_i^*},\ i=1,2,...,m \quad (7)$$

Step 7. Rank all the alternatives x_i in accordance with the values of relative closeness degree C_i $(i=1,2...,m)$. The larger the value of C_i the better of alternative x_i .

4. Case Study

Example 1. This example is taken from the case study conducted by Wang et al. [23]. The factory manager decided to purchase some machine facilities after sufficient discussion and complete evaluation. There are ten candidate machines $x_1,...,x_{10}$ are waited to be evaluated according to the following four attributes: Total purchasing cost (dollars) (o_1), Total floor space (m2) (o_2), Total machine number (o_3), Productivity (mm/min) (o_4). Here are the cost attributes, and others are benefit attributes. The original evaluation values are shown in Table 1 [23].

Table 1. Decision Matrix and Normalized Decision Matrix for Machine Group Selection in an FMC

No.	Evaluation attribute values				No.	Evaluation attribute values			
	o_1	o_2	o_3	o_4		o_1	o_2	o_3	o_4
1	581818	54.49	3	5500	1	0.1073	0.0904	0.0857	0.0993
2	595454	49.73	3	4500	2	0.1098	0.0825	0.0857	0.0812
3	586060	51.24	3	5000	3	0.1081	0.0850	0.0857	0.0903
4	522727	45.71	3	5800	4	0.0964	0.0758	0.0857	0.1047
5	561818	52.66	3	5200	5	0.1036	0.0873	0.0857	0.0939
6	543030	74.46	4	5600	6	0.1001	0.1235	0.1143	0.1011
7	522727	75.42	4	5800	7	0.0964	0.1251	0.1143	0.1047
8	486970	62.62	4	5600	8	0.0898	0.1039	0.1143	0.1011
9	509394	65.87	4	6400	9	0.0939	0.1093	0.1143	0.1155
10	513333	70.67	4	6000	10	0.0947	0.1172	0.1143	0.1083

The specific calculation steps of the proposed method are given as follows:

Step 1. The normalized attribute values are reported in Table1;

Step 2. In order to determine the relative weight of each criterion affecting the machine selection decision, a pair-wise comparison matrix, as shown in Table 2.

Table 2. Pair-Wise Comparison Matrix

Criteria	Cost	Total floor space	Total machine number	Productivity
Cost	1	1/3	1/4	1/2
Total floor space	3	1	1/2	2
Total machine number	4	2	1	3
Productivity	2	1/2	1/3	1

Using the group eigenvalue method, the attribute weights are obtained as follows:
W=(0.4306,0.1797,0.0930,0.2967)

Step 3. The positive ideal solution (PIS) and the negative ideal solution (NIS) are:
PIS =(0.1098,0.1251,0.1143,0.0812) and NIS=(0.0898,0.0758,0.0857,0.1155).

Step 4. The distance measures for each alternative to PIS (NIS) and the relative closeness are reported in Table 3.

Table 3. Distance Measures, the Relative Closeness and Ranking Result

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}
D_i^*	0.0294	0.0422	0.0346	0.0135	0.0283	0.0341	0.0318	0.0223	0.0212	0.0264
D_i^-	0.0273	0.0253	0.0255	0.0405	0.0270	0.0227	0.0285	0.0350	0.0396	0.0329
C_i	0.4815	0.3746	0.4240	0.7500	0.4875	0.4003	0.4724	0.6106	0.6510	0.5550
Ranking result	6	10	8	1	5	9	7	3	2	4

Then the ranking order is 4 - 9 - 8 - 10 - 5 - 1 - 7 - 3 - 6 - 2, which is the same as the one obtained in paper [19] using AHP method, and almost the same as the result using TOPSIS method as : 4 - 9 - 8 - 10 - 7 - 5 - 1 - 6 - 3 - 2. The desirable machine is the machine No. 4.

Example 2.

This example is taken from the case study conducted by Sun [24], which applied data envelopment analysis (DEA) to evaluate 21 CNC machines (lathes) in terms of system specifications and cost at the operational level. It aims at identifying a homogenous set of good systems, by measuring, for each machine, according to some attributes: the capital cost of a CNC machine, quoted in New Taiwanese Dollar (NT$), work capacity, machine body, spindle and tool turret. Work capacity is measured by the maximum machining diameter (mm) and machining length (mm). The machine body is measured by rapid traverse rates (m/min) of the X-axis and Z-axis. Rapid traverse rates of the X and Z-axes reflect the positioning capability of a turning center. The spindle is measured by spindle speed range (rpm). Spindle speed is the number of revolutions that a spindle can make in one minute and it allows a machine to maintain a constant cutting speed regardless of the part diameter. The tool turret is measured by the tool capacity. The fewer is the number of tools in the turret, the more is the time required to change the tools as selected for use in a particular program. Thus, seven criteria, i.e. capital cost (CC) spindle speed range (SS), tool capacity (TC), rapid traverse rate of X-axis (TX), rapid traverse rate of Z-axis (TZ), maximum machining diameter (MD) and maximum machining length (ML) are considered that affect the ability of a CNC machine to perform various manufacturing operations. In this example, the most suitable CNC machine is selected for small-size shell production from the available alternatives using TOPSIS method.

Table 4. Quantitative Information for 21 CNC Lathes [24]

No.	CNC Lathe	Evaluation attribute values						
		CC (o_1)	SS(o_2)	TC(o_3)	TX(o_4)	TZ (o_5)	MD(o_6)	ML(o_7)
1	YANG ML-5A	1200000	5590	8	24	24	205	350
2	YANG ML-25A	1550000	3465	8	20	20	280	520
3	YCM TC-15	1400000	5950	12	15	20	250	469
4	VTURN16	1100000	5940	12	12	15	230	600
5	FEMCO HL-15	1200000	5940	12	12	16	150	330
6	FEMCO WNCL-20	1500000	3465	12	6	12	260	420
7	FEMCO WNCL-30	2600000	3960	12	12	16	300	625
8	EX-106	1320000	4950	12	24	30	240	340
9	ECOCA SJ20	1180000	4480	8	24	24	250	330
10	ECOCA SJ25	1550000	3950	12	15	20	280	460
11	ECCOA SJ30	1600000	3450	12	15	20	280	460
12	TOPPER TNL-85A	1200000	3465	8	20	24	264	400
13	TOPPER TNL-100A	1350000	2970	8	20	24	264	400
14	TOPPER TNL-100AL	1400000	2970	12	24	30	300	600
15	TOPPER TNL-85T	1350000	3465	12	30	30	264	350
16	TOPPER TNL-100T	1450000	2970	12	20	24	300	400
17	TOPPERTNL-120T	1520000	2475	12	20	24	300	400

18	ATECH MT-52S	1376000	4752	12	20	24	235	350
19	ATECH MT-52L	1440000	4752	12	20	24	235	600
20	ATECH MT-75S	1824000	3790	10	12	20	300	530
21	ATECH MT-75L	1920000	3790	10	12	20	300	1030

The specific calculation steps of the proposed method are given as follows:

Step 1. As all these criteria considered for selecting the proper CNC machine having different units and dimensions, their values are first normalized using Eq. (1). The normalized attribute values are reported in Table 5.

Table 5. Normalized Decision Matrix of Quantitative Information for 21 CNC Lathes [24]

No.	CNC Lathe	Evaluation attribute values						
		CC (o_1)	SS(o_2)	TC(o_3)	TX(o_4)	TZ (o_5)	MD(o_6)	ML(o_7)
1	YANG ML-5A	0.1732	0.2870	0.1589	0.2783	0.2332	0.1695	0.1529
2	YANG ML-25A	0.2237	0.1779	0.1589	0.2319	0.1944	0.2315	0.2271
3	YCM TC-15	0.2021	0.3054	0.2383	0.1740	0.1944	0.2067	0.2048
4	VTURN16	0.1588	0.3049	0.2383	0.1392	0.1458	0.1902	0.2620
5	FEMCO HL-15	0.1732	0.3049	0.2383	0.1392	0.1555	0.1240	0.1441
6	FEMCO WNCL-20	0.2165	0.1779	0.2383	0.0696	0.1166	0.2150	0.1834
7	FEMCO WNCL-30	0.3753	0.2033	0.2383	0.1392	0.1555	0.2481	0.2729
8	EX-106	0.1905	0.2541	0.2383	0.2783	0.2915	0.1985	0.1485
9	ECOCA SJ20	0.1703	0.2300	0.1589	0.2783	0.2332	0.2067	0.1441
10	ECOCA SJ25	0.2237	0.2028	0.2383	0.1740	0.1944	0.2315	0.2009
11	ECCOA SJ30	0.2309	0.1771	0.2383	0.1740	0.1944	0.2315	0.2009
12	TOPPER TNL-85A	0.1732	0.1779	0.1589	0.2319	0.2332	0.2183	0.1747
13	TOPPER TNL-100A	0.1949	0.1525	0.1589	0.2319	0.2332	0.2183	0.1747
14	TOPPER TNL-100AL	0.2021	0.1525	0.2383	0.2783	0.2915	0.2481	0.2620
15	TOPPER TNL-85T	0.1949	0.1779	0.2383	0.3479	0.2915	0.2183	0.1529
16	TOPPER TNL-100T	0.2093	0.1525	0.2383	0.2319	0.2332	0.2481	0.1747
17	TOPPERTNL-120T	0.2194	0.1271	0.2383	0.2319	0.2332	0.2481	0.1747
18	ATECH MT-52S	0.1986	0.2439	0.2383	0.2319	0.2332	0.1943	0.1529
19	ATECH MT-52L	0.2079	0.2439	0.2383	0.2319	0.2332	0.1943	0.2620
20	ATECH MT-75S	0.2633	0.1946	0.1986	0.1392	0.1944	0.2481	0.2315
21	ATECH MT-75L	0.2771	0.1946	0.1986	0.1392	0.1944	0.2481	0.4498

Step 2. In order to determine the relative normalized weight of each criterion affecting the CNC machine selection decision, a pair-wise comparison matrix, as shown in Table 6.

Table 6. Pair-Wise Comparison Matrix

Criteria	CC	SS	TC	TX	TZ	MD	ML
CC	1	1	1	1/2	1	1/2	1
SS	1	1	1	1	1	3	2
TC	1	1	1	1	2	2	2
TX	2	1	1	1	1/2	1/3	1
TZ	1	1	1/2	2	1	1/2	1/2
MD	2	1/3	1/2	3	2	1	1
ML	1	1/2	1/2	1	2	1	1

Using the group eigenvalue method, the attribute weights are obtained as follows:
W=(0.0999,0.1764,0.1777,0.1152,0.1158,0.1863,0.1287)

Among the seven criteria, CC, TX and TZ is the non-beneficial attribute as their lower values are desirable; on the other hand, SS, TC, MD and ML is the beneficial attribute because their higher values are always preferable. Table 1 shows the criteria values for 21 alternative CNC machines (lathes).

Step 3. The positive ideal solution (PIS) and the negative ideal solution (NIS) are :
PIS =(0.1588,0.3054,0.1589,0.3479,0.1166,0.2481,0.4498)
and
NIS=(0.3753,0.1271,0.2383,0.0696,0.2915,0.1240,0.1441).

Step 4.The distance measures for each alternative to PIS (NIS) and the relative closeness are reported in Table 7.

Table 7. Distance Measures, the Relative Closeness and Ranking Result

Alternative	D_i^*	D_i^-	C_i	Ranking result
x_1	0.0440	0.0458	0.5102	3
x_2	0.0405	0.0387	0.4889	6
x_3	0.0419	0.0431	0.5072	5
x_4	0.0386	0.0467	0.5476	2
x_5	0.0537	0.0413	0.4347	13
x_6	0.0546	0.0325	0.3729	21
x_7	0.0459	0.0361	0.4400	12
x_8	0.0485	0.0402	0.4528	9
x_9	0.0451	0.0425	0.4854	7
x_{10}	0.0457	0.0337	0.4241	16
x_{11}	0.0478	0.0318	0.3996	19
x_{12}	0.0464	0.0375	0.4469	11
x_{13}	0.0489	0.0355	0.4211	17
x_{14}	0.0448	0.0408	0.4766	8
x_{15}	0.0512	0.0418	0.4492	10
x_{16}	0.0507	0.0352	0.4099	18

x_{17}	0.0533	0.0345	0.3926	20
x_{18}	0.0475	0.0361	0.4320	15
x_{19}	0.0372	0.0388	0.5100	4
x_{20}	0.0446	0.0342	0.4337	14
x_{21}	0.0351	0.0506	0.5905	1

Then the ranking order is 21 - 4 - 1 - 19 - 3 - 2 -9 - 14 - 8 -15 - 12 - 7 -5-20 -18 - 10 -13 -16 -11 -17 -6, which is almost the same as the one obtained in paper [24-25] using DEA method.

5. Conclusion

For the machine selection problem under flexible manufacturing system environment, we propose a new evaluation method. We first establish a MADM model for machine selection problem, and then develop group eigenvalue method to determine the attributes. Group eigenvalue method is an easy weighting method, and has some advantage over AHP method. Then the new machine selection method is proposed combining group eigenvalue method with TOPSIS method. A practical example is used to show the effective and feasible of the proposed method. The new method is easy and can be finished by computer software, such as Excel, matlab, and thus can be a suitable method for manufacturing firms.

For the future, we will extend the proposed for other management decision problems, such as material selection, robot selection, water quality evaluation etc. We will further develop new evaluation method for machine selection problem and extend evaluation methods for fuzzy machine selection problem which the evaluation attributes are expressed by fuzzy numbers, such as interval numbers, triangular fuzzy numbers.

Acknowledgments

This work is partially supported by National Natural Science Foundation of China (No. 71261009).

References

[1] H. T. Nguyen, S. Z. M. Dawal, Y. Nukman and H. Aoyama, "A hybrid approach for fuzzy multi-attribute decision making in machine tool selection with consideration of the interactions of attributes", Expert Systems with Applications, vol. 41, **(2014)**, pp. 3078–3090.

[2] D. Aloini, R. Dulmin and V. Mininno, "A peer IF-TOPSIS based decision support system for packaging machine selection", Expert Systems with Applications, vol. 41, **(2014)**, pp. 2157–2165.

[3] M. H. M. A. Jahromi and R. T. Moghaddam, "A novel 0-1 linear integer programming model for dynamic machine-tool selection and operation allocation in a flexible manufacturing system", Journal of Manufacturing Systems, vol. 31, **(2012)**, pp. 224–231.

[4] C. Moon, M. Lee, Y. Seo and Y. H. Lee", Integrated machine tool selection and operation sequencing with capacity and precedence constraints using genetic algorithm", Computers & Industrial Engineering, vol. 43, **(2002)**, pp. 605–621.

[5] R. V. Rao, "Decision Making in Manufacturing Environment Using Graph Theory and Fuzzy Multiple Attribute Decision Making Methods", Springier-Verlag, London, **(2013)**.

[6] H. Chtourou, W. Masmoudi and A. Maalej, "An expert system for manufacturing systems machine selection", Expert Syst Appl, vol. 28, **(2005)**, pp. 461-467.

[7] F. T. S. Chan and R. Swarnkar, "Ant colony optimization approach to a fuzzy goal programming model for a machine tool selection and operation allocation problem in an FMS", Robot Computer Integer Manuf, vol. 22, **(2006)**, pp. 353-362.

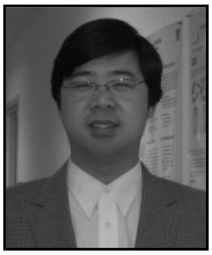
[8] F. T. S. Chan, R. Swarnakar and M. K. Tiwari, "Fuzzy goal-programming model with an artificial immune system (AIS) approach for a machine tool selection and operation allocation problem in a

flexible manufacturing system", International Journal of Production Research, vol. 43, **(2005)**, pp. 4147-4163.
[9] R. V. Rao, "Machine group selection in a flexible manufacturing cell using digraph and matrix methods", International Journal Ind Syst Eng, vol. 1 **(2006)**, pp .502–518.
[10] W. H, Qiu, "Group eigenvalue method", Applied Mathematics and Mechanics, vol. 18, no. 11, **(1997)**, pp. 1027-1031.
[11] J. J. Luo, J. J. Zheng, L. Sun and S. B. Zhang, "An entropy-based multi-criterion group decision analysis method of selecting the optimum weak-subgrade treatment", Journal of Chongqing University: English Edition, vol. 7, no. 3, **(2008)**, pp. 191-197.
[12] L. J. Jia and D. C. Fan, "A study of low carbon technology innovation project evaluation", Science & Technology Progress and Policy, vol. 29, no. 1, **(2012)**, pp. 128-132.
[13] M. A. Ying, "Relative Efficiency evaluation on water resource utilization", Journal of Northeast Agricultural University (English Edition), vol. 18, no. 3, **(2011)**, pp. 60-64.
[14] C. Kahraman, U. Cebeci and Z. Ulukan, "Multi-criteria supplier selection using fuzzy AHP", Logistics Information Management, vol. 16, **(2003)**, pp. 382–394.
[15] M. C. Das, B. Sarkar and S. Ray, "Decision making under conflicting environment: A new MCDM method", International Journal of Applied Decision Sciences, vol. 5, **(2012)**, pp. 142–162.
[16] O. Durán and J. Aguilo, "Computer-aided machine-tool selection based on a fuzzy-AHP approach", Expert Systems with Applications, vol. 34, **(2008)**, pp. 1787-1794.
[17] W. Z. Liu, "Group Eigenvalue Method for Food Supplier Selection Model with Ordinal Interval Preference Information", Advanced Journal of Food Science and Technology. vol. 6, **(2014)**, pp. 711-714.
[18] H. Chtourou, W. Masmoudi and A. Maalej, "An expert system for manufacturing systems machine selection", Expert Syst Appl, vol. 28, no. 3, **(2005)**, pp. 461–467.
[19] K. Maniya and M. G. Bhatt, "A selection of material using a novel type decision-making method: Preference selection index method", Materials and Design, vol. 31 **(2010)**, pp. 1785-1789.
[20] R. Rai, S. Kameshwaran and M. K. Tiwari, "Machine tool selection and operation allocation in FMS: Solving a fuzzy goal-programming model using a genetic algorithm", International Journal of Production Research, vol. 40, **(2002)**, pp. 641-665.
[21] A. Sadhu and S. Chakraborty, "Non-traditional machining processes selection using data envelopment analysis", Expert Systems with Applications, vol. 38, **(2011)**, pp. 8770–8781.
[22] R. V. Rao, "Decision Making in Manufacturing Environment Using Graph Theory and Fuzzy Multiple Attribute Decision Making Methods", Springer-Verlag, London, **(2007)**.
[23] T. Y. Wang, C. F. Shaw and Y. L. Chen, "Machine selection in flexible manufacturing cell: a fuzzy multiple attribute decision making approach", International Journal Prod Res, vol. 38, **(2000)**, pp. 2079-2097.
[24] S. Sun, "Assessing computer numerical control machines using data envelopment analysis", International Journal of Production Research, vol. 40, **(2002)**, pp. 2011-2039.
[25] S. T. Liu, "A fuzzy DEA/AR approach to the selection of flexible manufacturing systems", Computer Ind Eng, vol. 54, no. 1, **(2008)**, pp. 66–76.

Authors

Tonghua Yang, he is currently a doctoral student at School of Information Technology, Jiangxi University of Finance and Economics, China. He current major research fields include information management and knowledge management.

Shenghua Xu, she is a chief professor and doctoral supervisor in management science and engineering at Jiangxi University of Finance and Economics, China. She is also the associate chairman of academic committee in School of Information Technology. She has published about more than 50 research papers (including about 20 SCI/EI-indexed papers) and 2 books. Her current major research fields include information management and knowledge management.



Naixue Xiong, he is current a faculty at Dept. of Business and Computer Science (BCS), Southwestern Oklahoma State University (SWOSU), OK, USA. He received his both PhD degrees in Wuhan University (about software engineering), and Japan Advanced Institute of Science and Technology (about dependable networks), respectively. Before he attends SWOSU, he worked in Colorado Technical University, Wentworth Technology Institution, and Georgia State University for many years. His research interests include Cloud Computing, Business Networks, Security and Dependability, Parallel and Distributed Computing, and Optimization Theory.

Dr./Prof. Xiong published over 100 international journal papers. He served as an Editor-in-Chief, Associate editor or Editor member for over 10 international journals (including Associate Editor for IEEE Tran. on Systems, Man & Cybernetics: Systems, Associate Editor for Information Science, Editor-in-Chief for Journal of Internet Technology (JIT), and Editor-in-Chief for Journal of Parallel & Cloud Computing (PCC)). Dr./Prof. Xiong is the Chair of “Trusted Cloud Computing” Task Force, IEEE Computational Intelligence Society (CIS), http://www.cs.gsu.edu/~cscnxx/index-TF.html, and the Industry System Applications Technical Committee, http://ieee-cis.org/technical/isatc/; He is a senior member of IEEE Computer Society. E-mail: xiongnaixue@gmail.com, neal.xiong@swosu.edu.

